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The formation and stability of surface armoring by coarse sand particles

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Introduction

Considerable knowledge about the influence of coarse grains on sorting processes has been gained during past years. Bagnold (1941) indicated that sand removal must cause a progressive coarsening of the bed surface, when the wind strength was below the ultimate threshold, movement must cease after a certain interval of time, because the surface becames stabilized by the formation of a protective layer of grains sufficiently large to be immovable. Rasmussen and Mikkelsen (1991) also pointed out, that when grains were gradually exposed to the air flow, the average speed of creeping grains was less than that of saltating grains and the latter could progressively be blown away from the bed leaving the creeping grains as a residual armouring. As a result of sorting processes on an erodible surface, Yu and Okumura (2002) found that the positioning of coarser particles on erodible surfaces changed after an initial period, and an alignment of the coarser particles with wind direction was observed. The assembled coarser sand particles were more effective in protecting erodible sand than individual coarser particles. Even if the coarser particles on the erodible surface were not large enough to be immovable, the erodible surface would also become stabilized through positioning of assembled coarser particles (referred to as oriented assemble). Yu and Okumula (2002) suggested that the movement and stability of the oriented assemble would be related to interspaces of coarser particles on the surface in different wind condition.

The purpose of this study was to further rarefy the formation and stability of oriented assemble influenced under interspaces of topmost grains through a serial of wind tunnel experiments.

Materials and Methods

Experiments were conducted in an indoor wind tunnel with a 50cm×40cm (spanwise) in cross-section and 17m in length at the Arid Land Research Center of Tottori University, Japan. The dimension of the experimental section is presented in Figure 1. The sampling area was 10cm perpendicular to the stream and 20cm streamwise. A coarser sand layer ($2.00>d>0.84$mm, dyed black), with thickness of approximately one grain and 5 varieties of interspaces (Table 1), were placed on a top of the fine sand glued onto the tunnel bed. Interspaces sizes of coarser sands were estimated by the ratio of empty area (REA) which was obtained by calculating the ratio of the empty area to the total sampling area from photographs obtained with a digital camera system mounted on the tunnel roof. Coarser sands layers were intermittently exposed to 3 kinds of wind friction velocities (VL: 24, VM: 32 and VH: 39 cm/s; Willettss and Rice, 1988). Wind conditions and elapsed erosion time are

presented in Table 2. Before starting of each experiment and at 5 minutes intervals the sand trays were weighted and REA were measured.

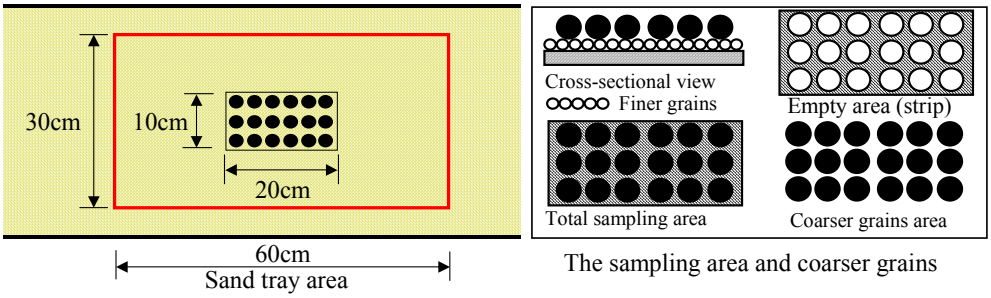


Figure 1. Dimensions of experimental section in wind tunnel.
REA: ratio of empty area (=Empty area (strip)/Total sampling area).

Table 1. Compositions of coarser sands layer on sampling area.

Sample	S5	S10	S15	S20	S25
Weight(g)	5.000	10.000	15.000	20.000	25.000
Weight per unit area(g/cm^2)	0.025	0.050	0.075	0.100	0.125
REA(%)	75.800	64.000	32.700	14.600	8.400

REA: ratio of empty area (=Empty area/Total sampling area).

Table 2. Wind condition and erosion time elapsed of the experiments.

	Time elapsed (min.)	0-5	5-10	10-15	15-20	20-25	25-50	50-55	55-60
PattenVL	Friction wind velocity	VL	VL	VL	VL	VL	VL	**VL**	VL
	Wind direction	→	→	→	→	→	→	←	→
PattenVM	Friction wind velocity	VM	VM	VM	VM	VM	VM	**VL**	VM
	Wind direction	→	→	→	→	→	→	←	→

	Time elapsed (min.)	0-1	1-2
PattenVH	Friction wind velocity	VH	VH
	Wind direction	→	→

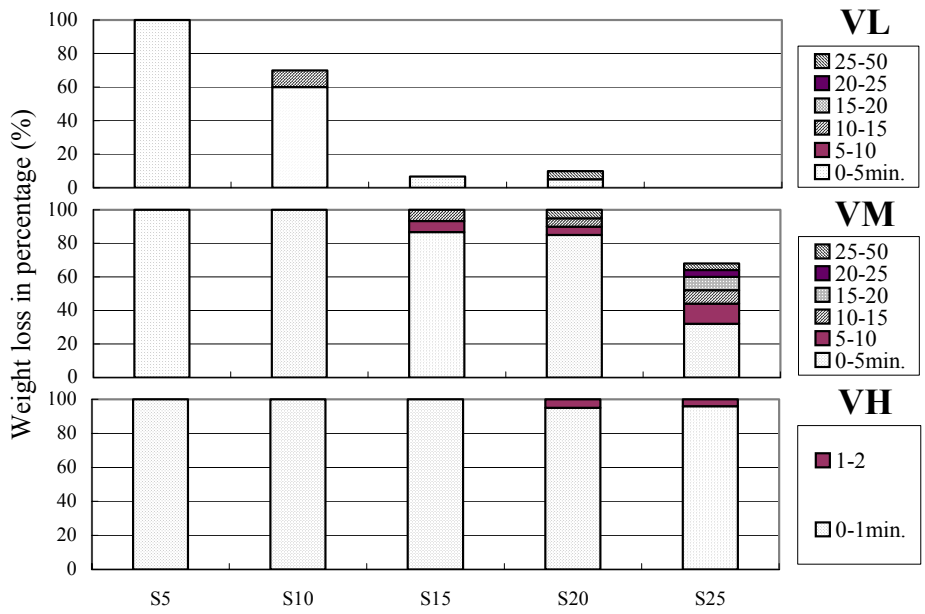
Results and Discussions

The effect of interspaces sizes on the oriented assemble

With the reduction of friction velocity and REA, more coarser sand particles were remained on the surface (Figure 1). After 50 minutes, most of the remaining coarser sand particles appeared on oriented assemble condition (Photo. 1) except S25 in the case of VL.

The residual coarser sands on the surface presented in the cases of VL and VM, which REA was as smaller as that of 33% and 15% respectively. However, in the cases of VH, the coarser sands layer was eroded completely in 2 minutes, even though the REA was below 9%. The phenomenon of oriented assemble can occur only for certain interspaces sizes of coarser sands. If the interspaces size is too large, all the sand grains will be blown away. On the other hand, if the interspaces size is too small, the sand grains cannot adjust their positions and the oriented assemble cannot form. The friction velocity is also an effective factor.

Figure 2. The weight loss of coarser sands in 3 kinds of friction velocity.



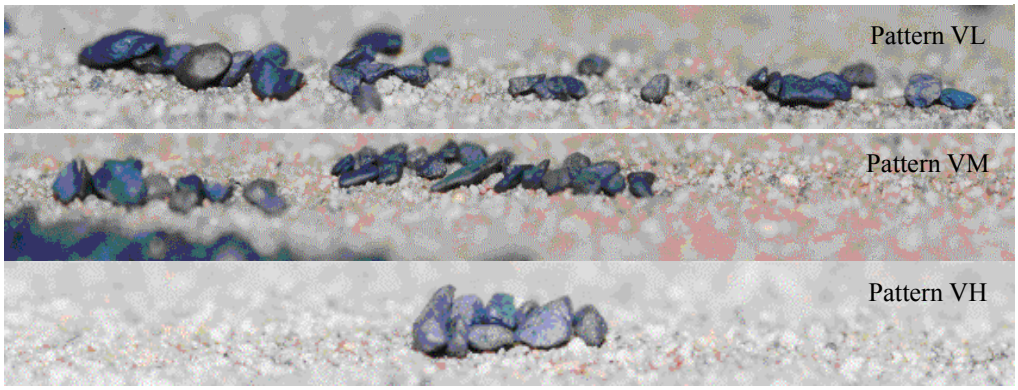


Photo. 1. The positioning of residual coarser sands after blowing.

The stability of oriented coarser sand

In a past research, it appeared that the surface of sorting process formed under some certain friction velocity, remained relatively stable as long as the friction velocity and direction were not changed. In the present study demonstrated the same result was obtained, indicating that with the initial formation of oriented assemble, even if erosion time increased to 50 minutes, the weight loss of coarser sands was less (Figure 2), and the oriented assemble remained stable (Photo.1). However, natural wind is changing all the time, and therefore the stability of oriented assemble under wind blowing from the opposite direction (counter-wind) was studied.

Figure 3 shows, the weight loss after 50 minutes of counter-wind most cases of VL and VM was decreased to an extreme low level. However, only with relative weak VL counter-wind of 5 minutes (from 50 to 55 minutes), coarser sands were removed, so was in the cases of VM. And then during the period of another 5 minutes from 55 to 60 min, with the wind of original direction and velocity, the weight loss was increased again in much higher level than that of volume in the end of 50 minutes. The oriented assemble, formed under a strong long-term wind, could be destroyed by a relative weak wind from the opposite direction. Moreover, inference is made that wind from the side would be destroy the oriented assemble too. The oriented assemble gets formed only when the wind blows from the original direction.

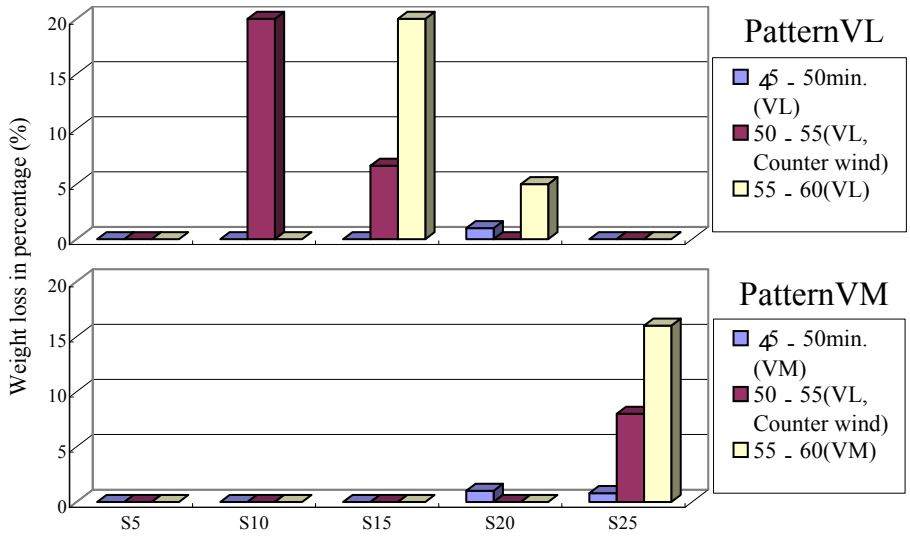


Figure 3. Changes of weight loss of coarser sands by counter-wind of VL.

Conclusions

As a result of sorting processes by wind erosion, the phenomenon of oriented assemble (armoring) can occur only for certain sized interspaces and function in original wind direction to stabilize the erodible surface.

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